

NASA-CR-195099

1N 37 - 12
204208
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Studies of Two Phase Flow

Final Report
for
NASA-JSC Grant NAG 9-546
UH Budget 1-5-54282

September, 1991-November, 1993

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February, 1994

(NASA-CR-195099) STUDIES OF TWO
PHASE FLOW Final Report, Sep. 1991
- Nov. 1993 (Houston Univ.) 4 p

N94-23594

Unclass

G3/29 0204208

INTRODUCTION

This grant was for the development of instrumentation for the support of our research in two-phase flow in simulated microgravity conditions. The funds have been expended in the development of a technique for characterizing the motion and size distribution of small liquid droplets dispersed in a flowing gas. Phenomena like this occur in both microgravity and normal earth gravity situations inside of conduits that are carrying liquid-vapor mixtures at high flow rates. Some effort to develop a conductance probe for the measurement of liquid film thickness was also expended.

MEASUREMENT TECHNIQUE

The technique that is being developed in our Heat Transfer/Phase Change Laboratory falls into the category of techniques called Reticle Image Velocimetry, or RIV for short. It can provide simultaneous velocity and diameter distribution at a fixed position in a liquid-vapor flow. It is an optical technique that uses coherent laser light as the basic means of detecting particles, in this case small droplets in the flow. RIV techniques have the advantages of easier optical alignment, lower operating frequencies, and being more economical than some other techniques like Phase Doppler Velocimetry.

The basic idea behind RIV is to use a Ronchi grating to break a laser beam into multiple beams and focus these beams into a two-phase flow. As particles pass through the grating beams, they refract light in such a way that a photodetector can produce a signal whose frequency is proportional to the velocity of the particle. The photodetector detects the individual grating beams as they pass over the detector as a result of the motion of the particles. We are using fiber optics for collecting the refracted laser light for ease of alignment. Figure 1 is a sketch of how the system is arranged. Another fiber optics/detector arrangement is used to determine the passage time of a particle, and this along with the velocity information yields the diameter of the droplet.

VERIFICATION OF THE TECHNIQUE

Various steps have been taken in verifying the applicability of this technique to the characterization of two-phase flows. Short summaries of these steps are given below:

Theoretical Background: The appropriate relationships between fringe grating characteristics, system configuration (photodetector/fiber optics configurations), and particle size and velocity have been developed. Predictions have been made using numerical techniques based on laws of geometrical optics. Predictions of the spread of the beam after they exit the grating have been made to verify the nature of the signal that should be expected. The relationship between grating size and the minimum size of particle that could be detected has also been studied. Other issues like non-sphericity of droplets, and the effect of multiple-droplet passing through the sample volume have been investigated.

The result is that we should be able to detect near-spherical droplets in the 10-100 μm range with the apparatus that we have developed.

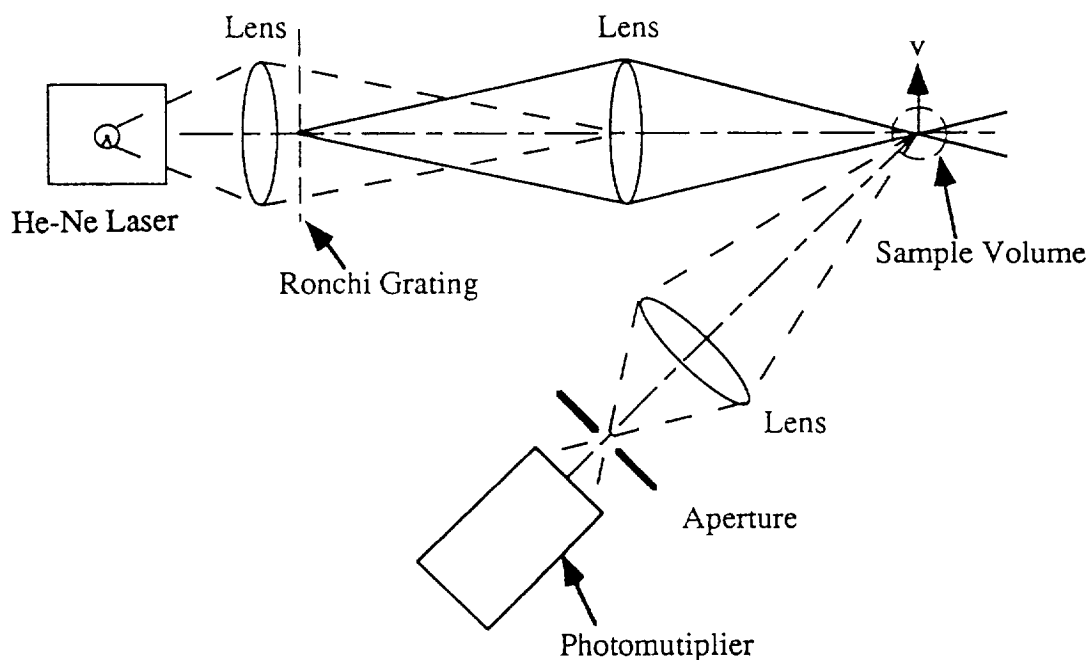


Figure 1. Layout of a Ronchi-grating RIV system.

Test Apparatus: Initially, we devised a system where a droplet of known size was dropped from a capillary tube through the sampling volume composed of the intersection space of the laser beam and the detector optics. The velocity of the droplet was also known from the distance through which it had dropped before passing through the sample volume. The success of this scoping work led to a more sophisticated test of the technique's applicability.

The method that we are currently using to verify the experimental technique uses a spray nozzle to produce a mixture of droplets and air. Manufacturer's data gives a rough estimate of the droplet sizes that should be produced. He-Ne laser light that has passed through the Ronchi grating is passed through a transparent wall of a chamber into which the spray issues. Fiber optics is used to sample the light that is refracted from the particles as they pass through a sample volume. Experiments show that the system configured as described above indeed is capable of measuring both droplet size and velocity.

Software Development: We have also developed the necessary software to acquire and manipulate the data using a PC. Methods to work out the spatial and temporal distributions of velocity and diameter have been developed and verified using the two experimental set-ups described above.

PROJECT SUMMARY

A technique for measuring the spatial and temporal droplet size and velocity distributions in two-phase (liquid-vapor) flows has been developed. Further refinement of the technique is being undertaken to adapt it to a wide range of experimental conditions. The eventual goal is to have a system that can assist us in gaining insight into two-phase flow typical of microgravity conditions.

ACKNOWLEDGMENTS:

This work was initially begun by Chris Struble, a NASA Fellowship holder. Frank Hsu is currently undertaking research and development work on the RIV system. The work will be the subject of Mr. Hsu's MS thesis. A copy of the thesis will be filed as an adjunct to this final report once completed.